Journal of Forensic and Legal Medicine 18 (2011) 110–114

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Original communication

Hair drug testing of children suspected of exposure to the manufacture of methamphetamine

Karen Farst MD, MPH, Assistant Professor [a,*], J.A. Reading Meyer MA, Research Assistant [b], T. Mac Bird MS, Research Associate [b], Laura James MD, Professor [c], James M. Robbins PhD, Professor [b]

[a] Section for Children at Risk, University of Arkansas for Medical Sciences, Department of Pediatrics, 1 Children's Way, Slot 512-24A Little Rock, AR 72202, USA
[b] Center for Applied Research and Evaluation, Department of Pediatrics, University of Arkansas for Medical Sciences, USA
[c] Section of Pharmacology and Toxicology, Department of Pediatrics, University of Arkansas for Medical Sciences, USA

ARTICLE INFO

Article history:
Received 12 July 2010
Received in revised form
29 November 2010
Accepted 25 January 2011
Available online 1 March 2011

Keywords:
Methamphetamine
Hair drug testing
Substance abuse
Child abuse
Child welfare

ABSTRACT

Introduction: This study compares hair color and age in children tested for methamphetamine by hair analysis due to suspicion of exposure to the manufacture of methamphetamine by their caregivers.
Methods: A retrospective analysis evaluated differences in hair drug testing results of 107 children less than 12 years of age tested due to clinical suspicion of having been exposed to the manufacture of methamphetamine. Results (confirmed by gas chromatography–mass spectroscopy) were compared for differences in likelihood of testing positive in relation to the subject's age and having light or dark colored hair and reported with crude and adjusted odds ratios with 95% confidence intervals.
Results: Of 107 children, 103 had a sufficient hair specimen for analysis. A third (36%) of the study population was less than 3 years of age. Almost half (45%) of the children tested positive for methamphetamine. 15% of the total study population tested positive for methamphetamine in combination with amphetamine indicating some degree of systemic exposure. No children were positive for amphetamine without also being positive for methamphetamine. Children less than 3 years of age were more likely to test positive. Positive hair drug tests for the combination of methamphetamine and amphetamine occurred in children with both light and dark colored hair.
Discussion and conclusion: Children living in homes where methamphetamine is being manufactured can have drug identified in their hair regardless of hair color. This testing can aid in illuminating the child's presence in an at-risk environment and a family in need of services.
© 2011 Elsevier Ltd and Faculty of Forensic and Legal Medicine. All rights reserved.

1. Introduction

Children may be harmed directly or indirectly from exposure to methamphetamine (MA) usage or production by their adult caregivers.[1] While MA may be ingested by children in quantities causing toxicity ranging from central nervous system agitation and tachycardia to hyperthermia and rhabdomyolysis,[2–4] children living in "clandestine" laboratories are also endangered by exposure to the caustic and flammable chemicals used in the drug manufacturing process.[1,5,6] They can be passively exposed to the drug itself during manufacture and usage through contamination of household surfaces and items by drug residue and vapor.[7,8]

Harm to children may also result indirectly due to the risk of physical and sexual abuse and neglect of children living in homes with substance abusing caregivers.[1,9] This risk may be accentuated by a higher rate of concomitant interpersonal violence[10,11] and psychiatric co-morbidities[12,13] among the parent-user.

Hair testing has been used in the adult population to identify drug use.[14,15] Steps are taken during analysis to remove drug on the surface of the hair so results will most closely reflect systemic exposure or personal usage.[15,16] The increased uptake of certain drugs by hair with higher melanin content poses a possible racial bias if drug is more likely to be detected in certain populations.[14,16,17] Other studies have suggested that detection of drugs in hair is consistent with varying drug preferences of the population being tested, as opposed to hair color bias alone.[18] Hair drug testing in children does not focus on discrimination between systemic and environmental exposure since it is being used to identify children and families in need of services instead of individual drug usage.[19] Therefore, the role of melanin uptake may not be as important a factor in the consideration of methodological bias as it is in the adult population.

* Corresponding author. Tel.: +1 501 364 2650; fax: +1 501 364 3939.
E-mail address: kfarst@uams.edu (K. Farst).

1752-928X/$ – see front matter © 2011 Elsevier Ltd and Faculty of Forensic and Legal Medicine. All rights reserved.
doi:10.1016/j.jflm.2011.01.013

Published reports of hair drug testing in children beyond gestational exposure are limited.[19–23] Discussion regarding racial bias in pediatric hair drug testing is limited to a single study of children who tested positive for cocaine and none of the blonde-haired children in the sample had positive results.[22]

This study describes our experience with hair testing in children suspected of living in a home where MA was being manufactured. Of specific interest were the impact of hair color and age on the results of MA hair testing.

2. Methods

With approval of the author's Institutional Review Board, medical records from Arkansas Children's Hospital were retrospectively reviewed for all children less than 12 years of age who had hair drug tests between September 2004 and September 2007. Records of children who were hair drug tested due to suspicion of exposure to MA production in a clandestine laboratory were included for analysis. Suspicion of having been exposed to a clandestine laboratory was defined as history provided to the treating physician from law enforcement agencies, children's protective services or family members of concerns relative to MA manufacture in the child's household. Children were excluded if hair drug testing was performed due to concerns of general drug use by a caregiver, or if testing was performed because of court ordered custody issues. One hundred and seven children were identified that met study inclusion criteria but four of the children did not have a sufficient quantity of hair collected for testing, leaving 103 children in the data set.

Hair collection was obtained by usingsterile scissors to cut a 100–200 mg section of hair as close to the scalp as possible from the vertex of the head and inserting the specimen into the collection kit of the United States Drug Testing Laboratories, Inc., Des Plaines, IL (USDTL). The collection envelope was sealed and transported to the local and reference laboratories by chain of custody. The specimen was marked as a *Child Guard*™ specimen per the reference lab instructions so the specimen would not be washed in the preparation phase to remove drug which had been deposited on the external shaft of the hair. Hair samples were screened after pulverization/rapid methanolic solvent extraction followed by high sensitivity Enzyme Linked Immunosorbent Assay (ELISA) drug analysis. Confirmation of ELISA results was performed using Gas Chromatography/Mass Spectroscopy (GC/MS). All of the samples were tested for 5 drugs of abuse (MA, Cocaine, Opiates, PCP and Cannabinoids). Detection limits for drugs in the testing panel are listed in Table 1.

The effect of hair color (blonde versus brown or black) and age (less than 3 years or 3–12 years) was examined in relationship to hair analysis results. Chi-square analyses were conducted to test differences in hair testing results in relationship to hair color and age.

Separate logistic regression models were used to analyze test results for MA and amphetamine (AMP). Multivariable models includedindicator variables for hair color and age. Both crude and adjusted odds ratios with corresponding 95% confidence intervals were reported. All analysis was conducted with SAS version 9.1 (SAS Institute Inc., Cary, NC).

3. Results

All patients in the sample were Caucasian (Table 2) in line with cultural preferences for MA usage. Almost a third (36%) of the study populationwas less than 3 years of age. Hair color was recorded in the medical record for 57% of the subjects; 30% had dark hair (brown or black), and 27% had blonde hair. Almost half (45%) of the study population tested positive for MA. 15% of the total study population had both MA and it's by-product from systemic degradation, AMP identified. Therefore almost a third of the patients testing positive for MA showed some degree of systemic exposure by testing positive for AMP as well (15/46 patients). None of the children tested positive for AMP alone..

Seven children had cocaine identified in their hair drug tests. Of these, five were also positive for MA. One child tested positive for oxycodone in addition to MA.

Urine drug testing was conducted during the same visit in 45 of the 103 children who had hair drug testing. One of the 45 urine tests was positive for MA and AMP (with MA also identified in the hair). Of the 44 patients with negative urine drug tests, 37 had positive hair drug tests including 25 for MA alone and 12 for MA and AMP (Fig. 1).

Co-morbid conditions were recorded in 16 of the 46 patients who tested positive for MA. Failure to thrive was identified among four, toxic ingestions in two, physical abuse in four, sexual abuse in two, dental neglect in one, burns in one, and cellulitis in two. Among the 57 children who tested negative for methamphetamine, ten were identified with co-morbid conditions. Physical abuse was identified among three, sexual abuse in one, dental neglect in four, and burns in two. These co-occurring conditions did not occur with a frequency that allowed statistical analysis of trends between positive and negative test results or between age groups.

As shown in Tables 3 and 4, children with dark hair color were no more likely to test positive for MA and MA plus AMP compared to children with blonde hair, as the adjusted odds ratios were not statistically significant (AOR = 2.79, CI 0.86–9.01 and 5.72, CI 0.99–33.2 respectively). Younger children (<3 years) were significantly more likely to test positive for MA alone (AOR = 2.65, CI

Table 1
Screening and cutoff detection levels for 5 drug hair tests.

Drug	Screening cutoff	Confirmatory cutoff
Methamphetamine	500 pg/mg	100 pg/mg
Cocaine	500 pg/mg	100 pg/mg
Opiates	200 pg/mg	
Morphine		100 pg/mg
Codeine		100 pg/mg
Hydrocodone		100 pg/mg
Hydromorphone		100 pg/mg
Oxycodone		100 pg/mg
6-MAM		100 pg/mg
Phencyclidine (PCP)	100 pg/mg	100 pg/mg
Marijuana (THC)	5.0 pg/mg	5.0 pg/mg

Child Guard™ hair drug test by United States Drug Testing Laboratories, Inc., Des Plaines, IL.

Table 2
Demographics and test results of children hair drug tested for suspicion of exposure to the manufacture of methamphetamine.

	Overall	Positive for Methamphetamine	Positive for Methamphetamine and Amphetamine
Demographics	N(%)	N(%)	N(%)
Race/Ethnicity			
Caucasian	103(100)	46(44.7)	15(14.6)
Hair Color			
Brown or Black	31(30.1)	13(41.9)	7(22.6)
Blonde	28(27.2)	7(25.0)	2(7.1)
Missing	44(42.7)	26(59.1)	6(13.6)
Age			
Under 3 Years	37(35.9)	25(56.8)	9(24.3)
3–12 Years	66(64.1)	21(37.9)	6(9.1)

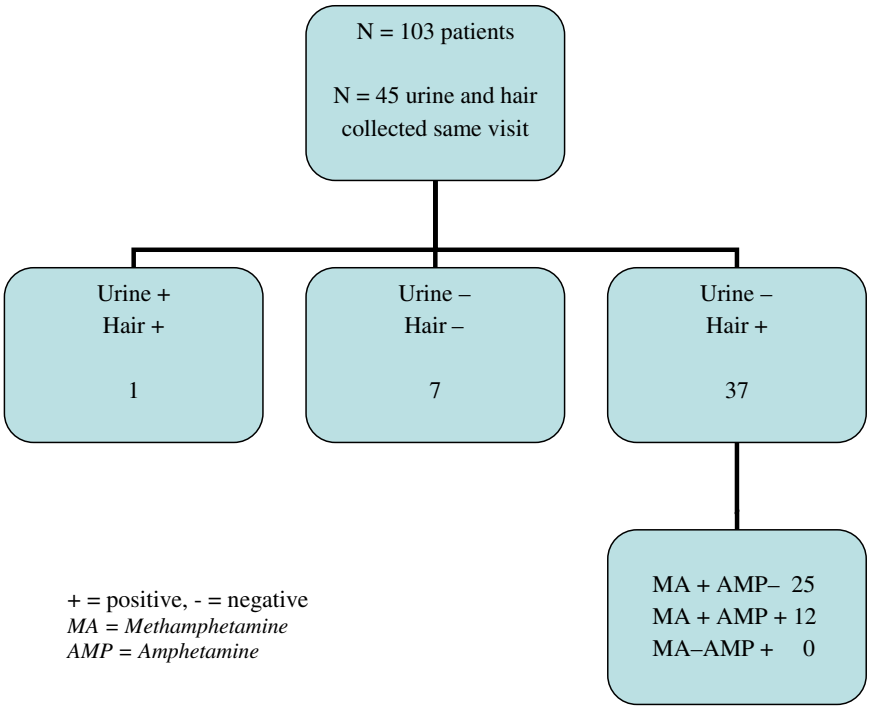

Fig. 1. Results of patients with both urine and hair drug testing performed simultaneously.+ = positive, - = negative, MA = Methamphetamine, AMP = Amphetamine.

1.08–6.48) as well as MA plus AMP than older children (AOR = 4.26, CI 1.28–14.1).

4. Discussion

The use of hair drug testing in children removed from clandestine MA laboratories has been reported previously.[21] However, this study provides comparison of hair color and age to the likelihood of testing positive for the drug not previously reported. Hair drug testing in children does not typically control for the possibility of passive, environmental exposure by pre-washing hair samples to remove drug on the outer surface of the shaft as it would in adults who are being tested for evidence of individual drug usage[15,16] since concern exists for welfare whether the child was exposed environmentally or systemically.[19] Therefore, hair color would not be expected to play as significant a role in the likelihood of testing positive as it has in animal and human studies that report an increased uptake of MA in hair with higher melanin content (darker hair). However, we did find that children with both dark and light colored hair could test positive in cases where some level of systemic exposure was being detected (ie. metabolism of MA to AMP occurs internally and not on shaft of hair).

We limited the study to children less than 12 years of age in an attempt to minimize the potential confounding variable of drug abuse/consumption by older children living in the homes with MA labs. Our entirely Caucasian sample, while consistent with cultural characteristics of MA use, did not allow for analysis of whether hair drug testing carries with it an inherent racial bias in children.

Our finding that younger children were more likely to have evidence of systemic exposure to MA was not unexpected. Not only are younger children more likely to spend more time indoors in a drug-endangered environment, they also spend more time closer to the ground, have higher resting respiratory rates, and frequently exhibit hand-to-mouth behaviors. These factors may contribute to increased systemic exposure to MA (which can occur through ingestion, inhalation, and sweat gland absorption) in young children living in drug manufacturing homes.[6] Even if children are not in the home at the time that MA is being "cooked," residue from the drug may be present throughout the home and found on food surfaces, utensils, carpeting and clothing.[7] Children found in an active clandestine MA laboratory may require decontamination by bathing and change of clothing to decrease risk of ongoing exposure to themselves and others.[1,6,24] Contamination with drug and chemical residue is potentially hazardous to first responders[25] and personal protective equipment is recommended for the individuals

Table 3
Odds of positive hair test for methamphetamine.

	OR	95% CI	AOR	95% CI
Hair Color				
Blond	Ref		Ref	
Brown or Black	2.17	(0.71–6.60)	2.79	(0.86–9.01)
Age				
3–12 Years	Ref		Ref	
Under 3 Years	2.15	(0.93–4.97)	2.65	(1.08–6.48)

Missing hair color included in all models as control variable.
Adjusted odds ratios include hair color and age in same model.

Table 4
Odds of positive hair test for methamphetamine and amphetamine.

	OR	95% CI	AOR	95% CI
Hair Color				
Blond	Ref		Ref	
Brown or Black	3.79	(0.72–20.1)	5.72	(0.99–33.2)
Age				
3–12 Years	Ref		Ref	
Under 3 Years	3.21	(1.01–10.2)	4.26	(1.28–14.1)

Missing hair color included in all models as control variable.
Adjusted odds ratios include hair color and age in same model.

entering one of these homes.[7] Emergency department (ED) personnel have reported adverse health events after caring for patients involved in MA lab mishaps that were not decontaminated prior to arrival in the ED.[26,27] These issues reinforce the importance of identifying potentially hazardous exposures occurring in the community beyond the obvious goal of identifying children whose caregivers may be in need of services related to substance abuse disorders.

Proactive identification of children living in a drug-endangered environment is limited by caregivers' reluctance to provide a history of drug use or production and by imprecision in urine drug testing methodologies. Reliance on urine as the test sample has numerous limitations that preclude it from being an ideal biological sample for the documentation of MA exposure in these vulnerable patients. Urine has a narrow window of detection for drugs of abuse because many drugs are eliminated within hours to days of exposure.[28,29] Grant showed that among children removed from MA laboratories, the drug was detected in urine for only 6 h after removal of the child from the drug manufacturing site.[30] The limit of detection for MA in urine for most standard drug screens are derived from workplace standards that are set to allow for the presence of a small amount of drug.[31] Positive screening urine tests by immunoassay should be confirmed by a direct identification method (e.g., GCMS) to avoid reporting a false positive result.[28,29]

The low percentage of positive urine drug tests among drug-exposed children in our study is likely due to the time lapse between the child's last exposure and specimen collection as well as the requirement for a level of systemic exposure that would result in detectable levels of drug in the specimen collected (while hair could detect both systemic and environmental exposure). At the time of this study there was no community protocol for timely medical evaluation of children removed from MA laboratories and few of the children were evaluated immediately after removal from the home environment. In most cases, the time since last possible exposure was not specifically charted. In cases of unclear history regarding the time of the child's last exposure to the drug-endangered environment, collection of both hair and urine may be prudent.Hair grows at rate of 0.6–3 cm/month.[14,16] Recent systemic exposures may not be detected if the sample is collected within a few days of the exposure.

Our study was limited by a small sample and missing hair color data on 43% of the sample. While there were other health issues in the children who tested positive for MA that may have been related to living in a drug-endangered environment (caustic ingestions, burns, fractures, allegations of sexual abuse), these conditions did not occur at high enough frequency to analyze for associations between these conditions and test results.

All children suspected of living in a home with an MA laboratory in the community were not necessarily tested during the study period. If a scene investigation was conclusive that an MA laboratory had been operating in a child's home, drug testing may not have been perceived as necessary. Furthermore, even though the child welfare and judicial systems voiced importance of the hair drug tests to the investigator during the study period, there has been no formal evaluation of the effect that a positive hair drug test had on the child's protective service's proceedings or impact it might have had on preventing future abuse or neglect to the child.

A negative hair (or urine) drug test in a child does not exclude substance abuse issues in their caregiver. Likewise, while a positive drug test in a child can be viewed as a risk factor when assessing a child's welfare, it should not be used as a sole indicator of parenting problems and drug testing should not be used to replace an assessment of the child's health, home environment and caregiver needs.[32] Future work in this area should focus on evaluation of outcomes (medical, psychosocial and legal) of having a positive or negative test for the presence of drugs due to a suspicion of exposure to a drug-endangered environment.

Conflict of interest

The authors have no commercial or proprietary interest in any drug, device, or equipment mentioned in the submitted article.

Funding

The project was supported in part by an internal faculty development grant of the University of Arkansas for Medical Sciences.

Ethical approval

The project was approved by the University of Arkansas for Medical Sciences Institutional Review Board.

Acknowledgments

The authors' appreciate technical information provided by United States Drug Testing Laboratories, Inc., Des Plaines, Illinois.

References

1. Wells K. Substance abuse and child maltreatment. *Pediatr Clin N Am* 2009;**56**:345–62.
2. Kolecki P. Inadvertent methamphetamine poisoning in pediatric patients. *Pediatr Emerg Care* 1998;**14**:385–7.
3. Ruha A, Yarema MC. Pharmacologic treatment of acute pediatric methamphetamine toxicity. *Pediatr Emerg Care* 2006;**22**:782–5.
4. Matteuci MJ, Auten JD, Crowley B, Combs D, Clark RF. Methamphetamine exposures in young children. *Pediatr Emerg Care* 2007;**23**:638–40.
5. Farst K, Duncan JM, Moss M, Ray RM, Kokoska E, James LP. Methamphetamine exposure presenting as caustic ingestions in children. *Ann Emerg Med* 2007;**49**(3):341–3.
6. Grant P. Evaluation of children removed from a clandestine methamphetamine laboratory. *J Emerg Nurs* 2007;**33**:31–41.
7. Martyny JW, Arbuckle SL, McCammon CS, Esswein EJ, Erb N, VanDyke M. Chemical concentrations and contamination associated with clandestine methamphetamine laboratories. *J Chem Health Saf* 2007;**14**:40–52.
8. National Jewish Health. *Methamphetamine contamination on environmental surfaces caused by simulated smoking of methamphetamine*. Available at, http://www.nationaljewish.org/about/mediacenter/pressreleases/y2005/meth_research_results.aspx; 2010. Accessed January 6.
9. Walsh C, MacMillan HL, Jamieson E. The relationship between parental substance abuse and child maltreatment: Findings from the Ontario Health Supplement. *Child Abuse Negl* 2003;**27**:1409–25.
10. Cohen JB, Dickow A, Horner K, Zweben JE, Balabis J, Vandersloot D, et al. Abuse and violence history of men and women in treatment for methamphetamine dependence. *Am J Addict* 2003;**12**:377–85.
11. Haller DL, Miles DR. Victimization and perpetration among perinatal substance abusers. *J Interpers Violence* 2003;**18**:760–80.
12. Kalechstein AD, Newton TF, Longshore D, Anglin MD, van Gorp WG, Gawin FH. Psychiatric co-morbidity of methamphetamine dependence in a forensic sample. *J Neuropsychiatry Clin Neurosci* 2000;**12**:480–4.
13. Hans SL. Demographic and psychosocial characteristics of substance-abusing pregnant women. *Clin Perinatol* 1999;**26**:55–74.
14. Pragst F, Balikova MA. State of the art in hair analysis for detection of drug and alcohol abuse. *Clin Chim Acta* 2006;**370**:17–49.
15. Boumba VA, Ziavrou KS, Vougioklakis T. Hair as a biologic indicator of drug use, drug abuse and chronic exposure to environmental toxicants. *Int J Toxicol* 2006;**25**:143–63.
16. Curtis J, Greenberg M. Screening for drugs of abuse: hair as alternative matrix: a review for the medical toxicologist. *Clin Toxicol* 2008;**46**(1):22–34.
17. Stout PR, Claffey DJ, Ruth JA. Incorporation and retention of radiolabeled S (+) and R (-) methamphetamine and S (+) and R (-) N (n-butyl) amphetamine in mouse hair after systemic administration. *Drug Metab Dispos* 2000;**28**(3):286–91.
18. Kelly RC, Mieczkowski T, Sweeney SA, Bourland JA. Hair analysis for drugs of abuse. Hair color and race differential or systematic differences in drug preferences? *Forensic Sci Int* 2000;**107**:63–86.
19. Klein K, Karaskov T, Koren G. Clinical applications of hair testing for drugs of abuse: the Canadian experience. *Forensic Sci Int* 2000;**107**:281–8.
20. Boroda A, Gray W. Hair analysis for drugs in child abuse. *J R Soc Med* 2005;**98**:318–9.
21. Mecham N, Melini J. Unintentional victims: Development of a protocol for the care of children exposed to chemicals at methamphetamine laboratories. *Pediatr Emerg Care* 2002;**18**:327–32.

22. Lewis D, Moore C, Morrissey P, Leikin J. Determination of drug exposure using hair: application to child protective cases. *Forensic Sci Int* 1997; **84**:123–8.
23. Hayek SN, Wibbenmeyer LA, Kealey LD, Williams IM, Oral R, Onwuameze O, et al. The efficacy of hair and urine toxicology screening on the detection of child abuse by burning. *J Burn Care Res* 2009;**30**(4):587–92.
24. National Alliance for Drug Endangered Children. *National protocol for evaluation of children found in drug labs, 2004*. Available at, http://www.nationaldec.org/home.html; 2009. Accessed August 17.
25. Burgess J, Barnhart S, Checkoway H. Investigating clandestine drug labs: adverse medical effects in law enforcement personnel. *Am J Indust Med* 1996;**30**:488–94.
26. Horton DK, Berkowitz Z, Kaye WE. Secondary contamination of ED personnel from hazardous material events, 1995-2001. *Am J Emerg Med* 2003;**21**(3):199–204.
27. Horton DK, Orr M, Tsongas T, Leiker R, Kapil V. Secondary contamination of medical personnel, equipment and facilities resulting from hazardous material events, 2003-2006. *Disaster Med Public Health Prep* 2008;**2**(2):104–13.
28. Woolf AD, Shannon MW. Clinical toxicology for the pediatrician. *Pediatr Clin North Am* 1995;**42**(2):317–33.
29. Moeller KE, Lee KC, Kissack JC. Urine drug screening: practical guide for clinicians. *Mayo Clin Proc* 2008;**83**:66–76.
30. Grant P, Bell K, Stewart D, Paulson J, Rogers K. Evidence of methamphetamine exposure in children removed from clandestine methamphetamine laboratories. *Pediatr Emerg Care* 2010;**26**(1):10–4.
31. Kwong TC, Shearer D. Detection of drug use during pregnancy. *Obstet Gynecol Clin North Am* 1998;**25**(1):43–64.
32. McGuinness TM, Pollack D. Parental methamphetamine abuse and children. *J Pediatr Health Care* 2008;**22**(3):152–8.